University of Tehran
School of Electrical and Computer Engineering

Course:	**8101642 – Biomecanics of Legged Locomotion.**
Course type:	EE*: Com ☐ E ☐ P ☐ B ☐ Con ☐ D ☐ — CE*: SW ☐ HW ☐ IT ☐ MI ☐ — Credit: 3 Required ☐ — Elective ☒
Level:	Undergraduate ☐ Graduate ☒
Co-requisite(s):	None.
Prerequisite(s):	None.
Prerequisite by topic:	Robotics (8101187).
Textbook(s):	[1] M. A. Sharbafi, A.Seyfarth, *Bioinspired Legged Locomotion*, Elsevier, 2017. [2] D. A. Winter, *Biomechanics and motor control of human movement,* John Wiley & Sons, 2009. [3] M. H. Raibert, *Legged robots that balance*, MIT press, 1986. [4] T. A. McMahon, *Muscles, reflexes and locomotion*, Princeton: Princeton University Press, 1984. [5] R. M. Enoka, *Human kinetics Neuromechanics of Human Movement* 4th edn (Champaign, IL: Human Kinetics), 2008. [6] R. M. Alexander, *Principles of Animal Locomotion*, Princeton University Press, 2003**.**
Coordinator:	Dr. Sharbafi, Assistant professor, School of ECE.
Goals:	To familiarize the audience with legged locomotion modeling and control approaches which can be used in human/animal gait analysis designing assistive devices and legged robots.
Outcome:	Upon successful completion of the course, students will be able to 1. do basic analysis of different kinds of gaits; 2. work on existing locomotion models to investigate new controllers; 3. develop new dynamic models of legged locomotion; 4. do research on designing and developing legged robots based on biological inspiration; 5. do research on designing assistive devices like prostheses or orthoses.
Topics:	**1. Modeling 1(conceptual models):** • Template and anchor concept; • Locomotor sub-functions: Stance, leg swinging and balancing; • IP (Inverted pendulum) and LIPM (Linear IP Model); • SLIP (Spring loaded inverted pendulum model);

	• Pendulum model for leg swinging; • VPP (virtual pivot point) concept for balancing. • FMCH (force modulated compliant hip) model as a template for balancing. **2. Modeling 2 (Neuromuscular models):** • MTC (Muscle Tendon Complex); • Activation dynamics, force-length and force-velocity Relationships; • Hill-type Muscle Models; • Actuators as artificial muscles: pneumatic, series elastic and variable impedance actuators. **3. Control:** • Stability definition in legged dynamics: Standing, walking hopping and running; • Compliance role in control; • Body morphology role in simplifying control: Segmented leg, bi-articular muscles, wobbling masses and foot design; • Control approaches developed by engineers: ❖ ZMP (zero moment point) and capture point; ❖ Control based on passive dynamic walking; ❖ HZD (Hybrid Zero dynamics); ❖ VMC (virtual model control) and impedance control. • Motor control in biological systems: ❖ Muscle motor patterns in legged locomotion; ❖ CPGs (Central Pattern Generators); ❖ Reflex control; ❖ CPG vs reflex control. • Samples of bio-inspired engineering based control approaches: ❖ HZD with bio-inspired virtual constraints; ❖ Inverse optimal control; ❖ Template model based humanoid control.
Computer usage:	Implementing the homeworks and projects using Matlab Software.
Assignments:	4 to 5 homeworks, covering different topics.
Projects:	Arbitrary Projects related to the course topics.
Grading:	Assignments: 30% Projects: 35% Midterm exams: 0% Final exam: 35%
Further readings:	Course materials are based on different books and papers.
Prepared by:	Dr. Mazair Ahmad Sharbafi.
Date:	November, 1, 2017.

*EE: Electrical Engineering		CE: Computer Engineering	
Com	Communications	SW	Software
E	Electronics	HW	Hardware
P	Power	IT	Information Technology
B	Bioelectronics	MI	Machine Intelligence and Robotics
Con	Control		
D	Digital System		